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ERROR DETECTION AND CORRECTION

IN A TIME DECODING SYSTEM

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Introduction

The data reduction facilities at the Goddard Space Flight Center process magnetic tapes containing data received from the scientific satellites. The time code which indicates the data reception time in Universal Time is produced by a time encoder located in the tracking station and is serially recorded on a channel of the tape adjacent to those on which the incoming data are being recorded. Tracking networks and supporting computer facilities correlate the satellite's location in space with time, and receiving networks and data reduction facilities correlate the satellite's data with time. Since a majority of the data from the satellites thus use time as an independent variable in correlating data with position, erroneous time readings are a source of genuine concern to the experimenters. In order to reduce the time reading errors to a minimum, an error detecting and correcting time decoder has been designed for use with the data reduction facilities at Goddard. This system will first be used for processing data from S-17 (the second of the Orbiting Solar Observatory series).

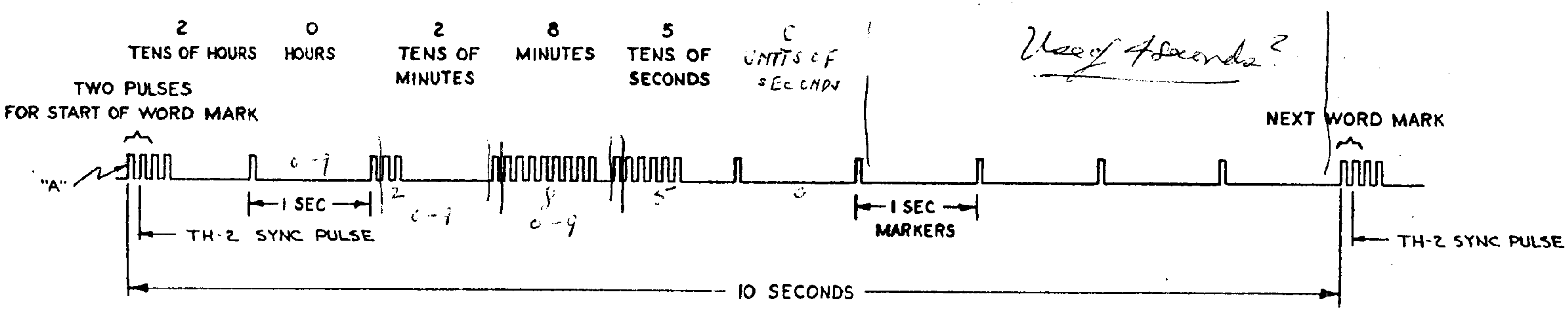
Time Codes

The two time codes adopted for use by the Goddard Space Flight Center are the serial decimal (SD) time code and the binary coded decimal (BCD) time code.

The Serial Decimal Time Code

The serial decimal time code consists of time data in digits from tens of seconds through tens of hours. Figure 1 shows this code. The resolution of the serial decimal time code is one second; however, the

NASA SERIAL DECIMAL TIME CODE



TIME AT POINT "A" = 20 HOURS, 28 MINUTES, 50 SECONDS

NASA BCD TIME CODE

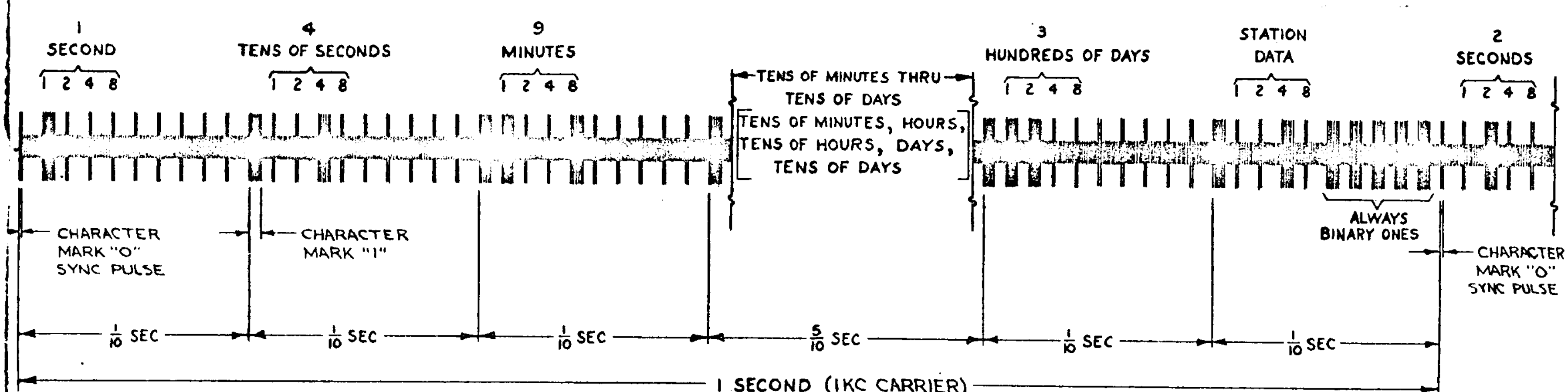


FIGURE 1

Of what use in last 4 sec's dec. code?

resolution can be improved to one millisecond with the use of a linearizing (reference) frequency, which is either 100 kilocycles (KC) or 10 KC and is derived from the same tracking station precision oscillator from which the time code is derived. Frequency modulation is used for recording this signal on tape.

The BCD Time Code

The BCD time code presents time data in digits from seconds through hundreds of days. This includes four bits per second of "station data" to identify a magnetic tape recording by including, for example, station identification, satellite identification, the year of recording, etc. The resolution of the BCD time code is one millisecond because the 1 KC carrier frequency is a part of the code. A binary zero is represented by an approximate three to one increase in the voltage amplitude of the carrier for two complete cycles. A binary one is represented by a similar carrier voltage increase for six complete cycles. Figure 1 shows the 1 KC coded carrier. The spectrum of the BCD time code includes no significant energy more than $\pm$ 400 cycles away from the 1 KC center frequency; therefore, this code can be mixed with other signals on a single channel of a tape recording to conserve channels. At present, the servo signal, which is 60 cycles per second modulation of 18.24 KC, is mixed with the BCD time code. The decoders previously available, however, have not been able to do an adequately reliable job of decoding this time code, because the signal strength and signal-to-noise ratio have had wide variations among the ensemble of tapes received from the receiving stations, and the decoders have been unable to cope with these variations.

Present Methods of Time-Data Correlation

In the data reduction process at Goddard, the two methods previously used for correlating time with data are the multiple-read-in method and the single-read-in method. In the multiple-read-in method the decoder collects the time data from the magnetic tape and formats the data as a single time reading; once every ten seconds for Serial Decimal, or once per second for BCD. This reading is updated by 1 KC pulses until another full time reading is collected. The main disadvantage with this method is that any temporary perturbation in time signal appears as an error in the time reading. In the single read-in method the operator observes the register display and when it appears to be monotonically increasing, he transfers the decoded time word from the decoder into a register where it is updated with 1 KC pulses. The main disadvantages of this method are that only one time reading is actually correlated with the data, and that potentially valuable data are lost each time the register is reset, since the operator must wait several seconds to be sure that the decoder output is increasing monotonically before setting the updating register.

Sounds as tho a computer program could be used to detect aberrant pulses.

Figure 2 shows various possible errors in, and conditions of, a decoder's output. Undetected errors in the time readings associated with data can increase the cost of the data reduction process. In later

POSSIBLE CONDITIONS OF A TIME DECODER OUTPUT

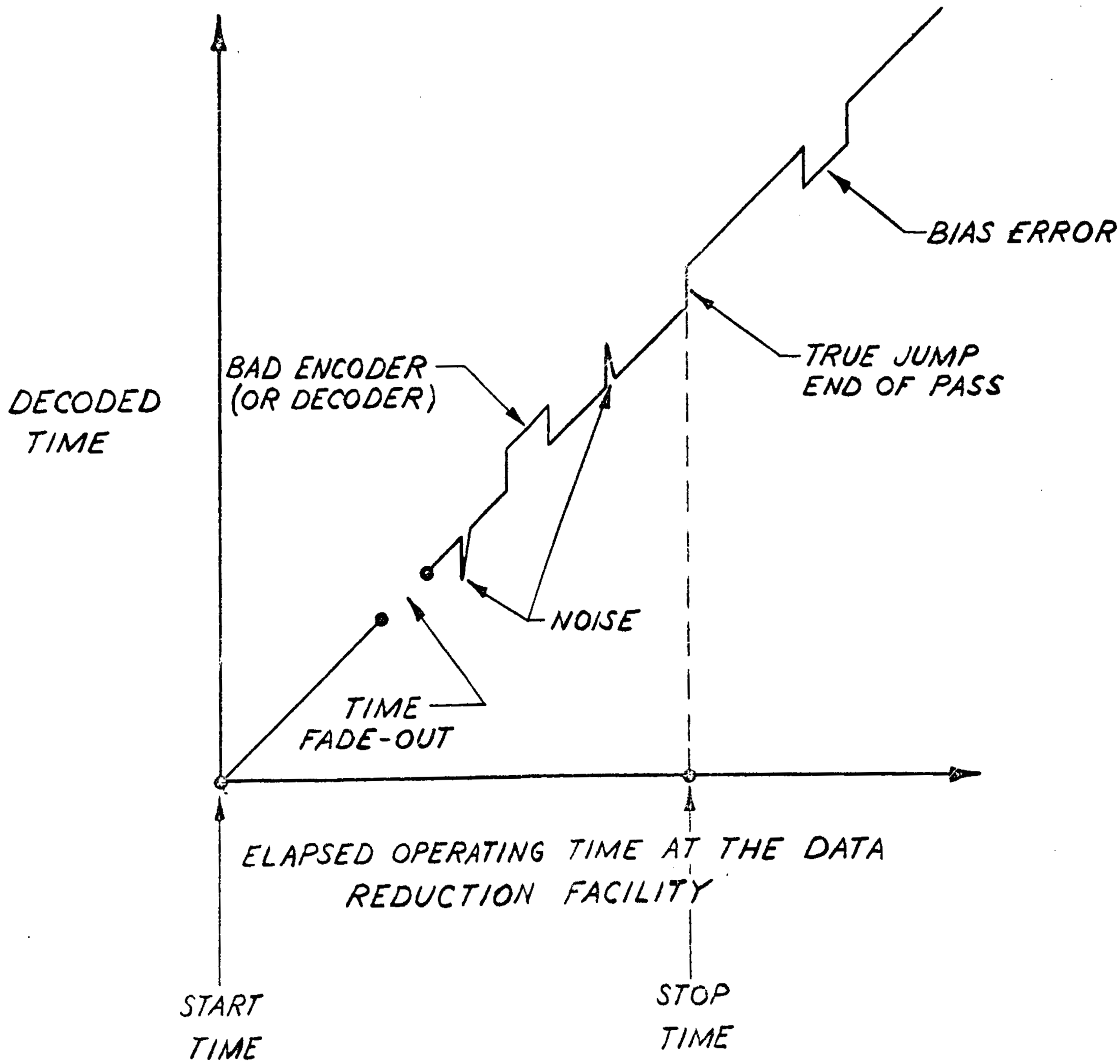


FIGURE 2

processing of the data, general purpose computers are used to perform such operations as scaling, converting, sorting, and other special arithmetic or formatting operations as may be necessary for a specific set of data. If undetected errors in the time data are recorded on the digital magnetic tape, computer time must be spent in searching for these errors. For PFM telemetry, the digital tape is formatted to have a time reading once per frame, which occur at approximately constant time intervals. The computer measures the difference between two consecutive time readings; and if this difference falls outside certain tolerance limits, an error is indicated.

The Systems Approach to Time Error Detection

The engineering problem is in choosing and designing a system which, while minimizing operator intervention, optimizes the trade-off of cost-complexity vs. index of confidence in its output readings. The ideal system would be one that could provide correct time readings regardless of errors in the input signal. A more realistic system is one for which the output can be assigned an index of confidence which is a function of the condition of the input signal and the cost and complexity of the system. The final choice of an optimum system depends upon the statistics of the probability of occurrence of any given type of error.

Categorizing Errors

The systematic design of a system which deals with errors requires categorizing those errors. There are several ways to classify these errors, e.g., firstly, those caused by the encoder, decoder, by transmission link; secondly those caused by equipment, or by the operators.

The most useful categorization seems to be the consideration of the various conditions which can be assumed by the signal at the input to the decoding system. Malfunction of the decoding equipment can be shown to be equivalent to some of these input signal conditions. With this in mind, the listing Tabel A was prepared. (See Table A)

TABLE A

Conditions of the signal arriving in the Data Reduction Facility

I. The BCD code exists:

1. It is correct
2. It is incorrect sporadically
3. It is incorrect regularly (bias)

II. The BCD code doesn't exist:

4. temporarily
5. permanently

III. The SD code exists:

6. It is correct
7. It is incorrect sporadically
8. It is incorrect regularly (bias)

IV. The SD code doesn't exist:

9. temporarily
10. permanently

V. The Linearizing frequency exists

11. It is correct

12. It is incorrect sporadic

13. It is incorrect regularly (bias)

VI. The Linearizing frequency doesn't exist

14. temporarily

15. permanently

The conditions can exist in only eight possible combinations

Category	II & IV & V	Category	II & IV & VI
"	II & III & V	"	II & III & VI
"	I & IV & V	"	I & IV & VI
"	I & III & V	"	I & III & VI

The other combinations are impossible because categories I & II, categories III & IV, and categories V & VI are mutually exclusive.

An Identification and Correction System

This system detects and identifies errors and corrects certain types of errors. In addition, it provides time readings as pure binary numbers which express either the number of elapsed milliseconds of the year, or the number of elapsed milliseconds of the day and the day of the year, as well as the mixed modulus system where time is put on the digital magnetic tape as a BCD number indicating the day of the year, hour of the day, minute of hour, etc. Providing both formats helps eliminate costly conversion time later in the data analysis process.

The time decoding system which is being built has been designed to consider: (1) a low signal-to-noise ratio at its input, where noise includes white noise, impulsive noise, and stray modulation; (2) genuine errors in the input signal which may be caused at the encoder: (3) signal fade-out; and (4) decoder malfunction.

There are only four combinations of bad input signal in Table A which will render incorrect output readings without the system recognizing that its output is incorrect. These four combinations are:

1. (3,8) a BCD bias error and a SD bias error where the two bias errors are equal.
2. (3,10) a BCD bias error and no SD code anywhere on the tape.
3. (5,8,11) no BCD code anywhere on the tape, a SD bias error.
4. (5,8,14) no BCD code anywhere on the tape, a SD bias error, and the linearizing frequency missing for very short periods of time.

The seriousness of these limitations, of course, depends upon the nature of the input signal, the frequency of occurrence of the unmanageable input signal combinations, and the consequences of allowing uncorrected errors. After a careful consideration of these factors, it was presumed it would not be economically justified to design features into the system to compensate for these irregularities.

There are three inputs to the system; (1) the BCD time code, (2) The Serial Decimal (S.D.) time code, and (3) a linearizing frequency.

The following is a brief description of the elements of the block diagram of the proposed system (See Figure 3).

TIME DECODER BLOCK DIAGRAM

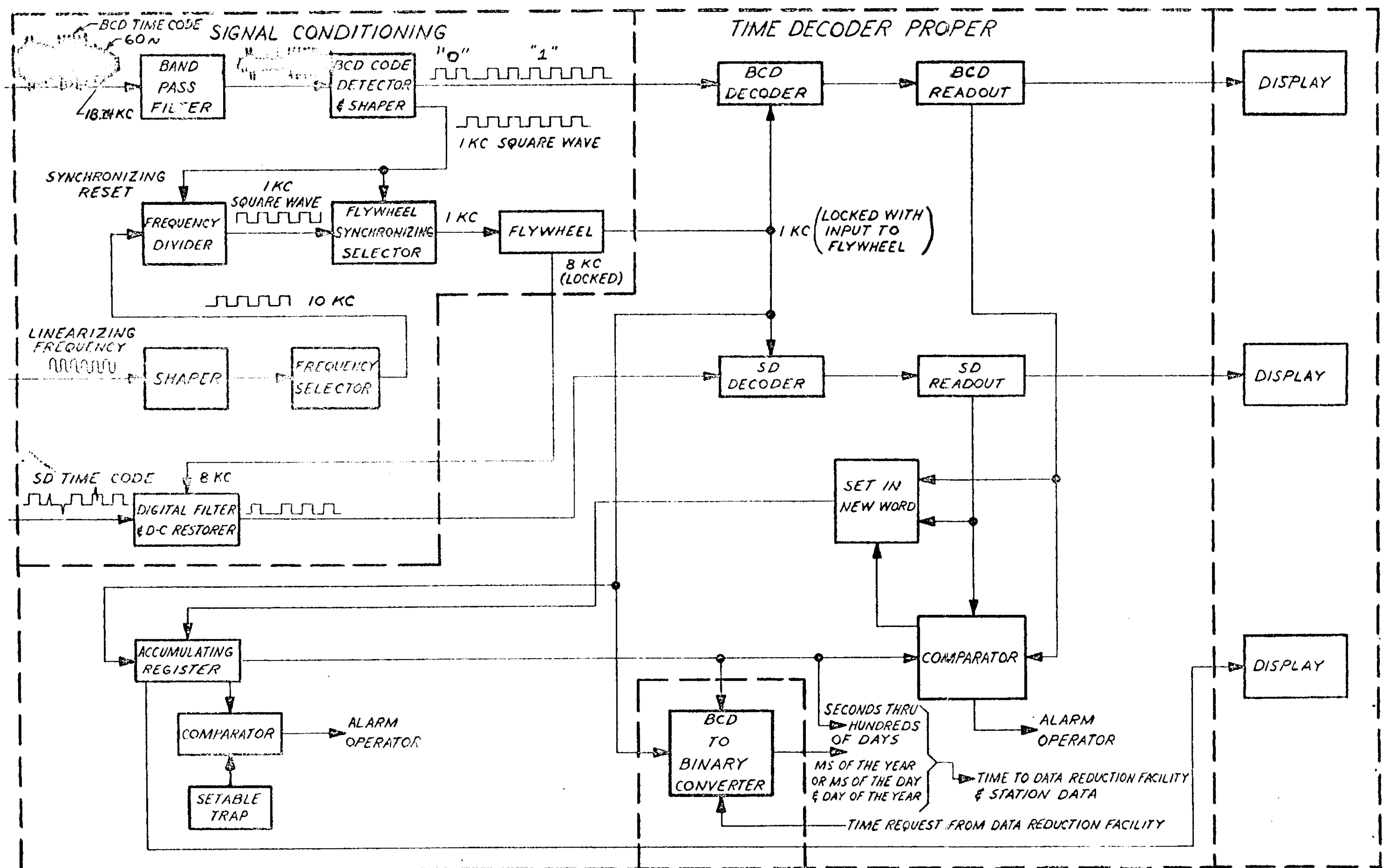


FIGURE 3

A. Band Pass Filters

These filters were designed to extract the BCD time code from the incoming signal which can also contain an 18.24 KC carrier frequency that is amplitude modulated with 60 cycles for tape speed control. The filters have been designed to attenuate both the carrier and the servo signal at time compressions of 1, 2, 4, 8, and 16, (i.e., tape speed-ups). The band width of the 1 KC filter is 800 cycles. These filters are conventional T-type capacitor and inductor low pass-high pass filters.

B. BCD Code Detector

The purpose of this code detector is to accept and adequately deal with amplitude variations of the input signal. It will handle variations of from 2.0 to 13.0 volts peak-to-peak. It also demodulates the time code from the carrier.

C. BCD Decoder

This unit discriminates between the "ones" and "zeros" of the BCD time code and presents this decoded time to the read-out circuitry. The BCD decoder contains a "one" detector circuit, sync shift pulse generator, sync pattern recognizer, sync shift register, logic counter, binary input error detection logic, binary shift register, and a binary word generator.

D. BCD Readout

This unit receives the decoded BCD time word in parallel form from the shift register in the BCD decoder unit and holds each decoded word for display and for making comparisons.

E. Display Units

Each decoded word is displayed to facilitate operation and maintenance. Each display unit contains "Nixie" drivers, binary-to-decimal converter units, and miniature "Nixie" tubes for display.

F. Shaper, Frequency Selector, Frequency Divider, and Flywheel Synchronizing Selector

Two different "real time" linearizing frequency signals, 100 KC or 10 KC may be available to the time decoder. They are shaped with a Schmitt Trigger circuit. If the input is the 100 KC signal, it is divided down to 10 KC in the "frequency selector". If the input is the 10 KC signal, it is passed straight through this selector. The 10 KC out of the frequency selector is again divided by ten in the "frequency divider" in order to produce 1 KC. The frequency divider is reset by the 1 KC carrier from the BCD code detector to assure that synchronization exists between both 1 KC signals entering the flywheel synchronizing selector. This selector supplies 1 KC to the flywheel from the linearizing frequency if that signal is present. If, however, the linearizing frequency fades out, the 1 KC from the BCD detector will automatically be used to drive the flywheel.

G. Flywheel

The purpose of the flywheel is to produce a nominal 1 KC signal which is phase-locked to its input, if there is an input, and to maintain an output at the frequency of the last input if the input disappears. The flywheel has a selectable bandwidth of $\pm$ 5% or $\pm$ 10%. This means that the standard frequency at the input can vary as much as the selected bandwidth and yet the output of the flywheel will continue to maintain phase-and-frequency-lock with its input. This will compensate for input tape stretch, or input tape recorder speed variation, etc. The flywheel also supplies the 8 KC signal to the Serial Decimal decoder front-end circuitry.

H. Digital Filter and D.C. Restorer Units

The Serial Decimal code signal consists of pulses which are 40 to 45 milliseconds wide and occur at a rate of ten pulses per second. Such a wide-band signal is susceptible to degradation by impulsive and white noise which makes the reading of this code susceptible to error. Digital techniques are employed to extract this signal from the noise. The DC voltage of the base line of these input pulses varies between plus one-half volt and minus one-half volt. A DC restoring circuit is used to assure a constant bias level to the input of the decoder.

I. Serial Decimal Decoder

The decoder is used to find synchronism in the Serial Decimal time code and present the decoder time to the readout register. It also checks the Serial decimal system by way of a word generator.

J. Serial Decimal Readout

This unit receives the Serial Decimal decoded time word in parallel from the Serial Decimal Decoder and holds this information for ten seconds for display and for making comparisons with the decoded BCD word or the accumulating register.

K. Accumulating Register

The use of an accumulating register prevents possible sporadic errors in either of the decoded time words from being passed to the rest of the data reduction facility. The time, as decoded in either the Serial Decimal or BCD decoders, is automatically set into the accumulating register at the beginning of each data reduction run and/or when the mode of operation switches between loops 1 and 2. The register is then updated by the 1 KC output of the flywheel. This accumulated time is available as an output and is also sent to the BCD-to-binary converter which presents time (ms of the day and day of the year or ms of the year) to the data reduction facility. The BCD output of the accumulating register is programmable.

L. "Comparator" and "Set in New Word"

The "Comparator" compares the decoded time with the accumulated time in the accumulating register. It also serves to make comparisons between the serial decimal and BCD decoded time words. The "set in new word" unit operates in conjunction with the comparator to set a new word in accumulating register when the accumulating register is deemed incorrect. The comparator detects errors in the input signal and errors in the equipment itself, and is, therefore, one of the most basic elements of the system.

M. BCD-to-Binary Converter

This unit converts the time word in the accumulating register (seconds through hundreds of days) to a binary number representing either milliseconds of the year or milliseconds of the day and day of the year. This converted time word is presented to the data reduction facility upon electronic request. The format of this output is programmable.

The converter is designed to make an automatic internal test for component malfunction prior to every conversion. If the automatic test procedure indicates a component malfunction, an error light will warn the operator and the output will be flagged. The light will remain lit until the malfunction is repaired and then it will be extinguished automatically.

N. "Setable Trap"

The purpose of this trap is to aid the operator in locating a specific time among the ensemble of incoming time words. It consists of a "Digiswitch" and a comparator. A number is set on the Digiswitch and a comparison is made between this number and the word in the accumulating register. When the number in the accumulating register is equal to or greater than the number on the Digiswitch the operator will be alarmed.

This decoder makes use, when possible, of the built-in redundancy of having both the BCD and Serial Decimal (S.D) time signals available for processing. If only one of these two signals is present, it automatically considers only that one. The decoder automatically checks its internal circuitry, identifies (flags) the class of error which it has detected, can automatically delete the output and alert the operator when the time-density of errors exceeds some preset value, alerts the operator and deletes the output at previously known preset times. The feature of alarming the operator at some preset time permits the immediate automatic detection of known times, such as the end of the recording of a particular satellite pass. This feature is expecially useful when more than one pass is recorded on one analog magnetic tape.

The system requires no starting procedure or starting point on the data tape. Unlike other time decoders, this system has neither manual single-read-in nor multiple-read-in modes of operation. It performs these operations automatically whether BCD or SD or both time codes are available.

The attached functional logic diagram (Figure 4) of the time decoder shows its various modes of operation. If the system has been reset, either by the system normalizer when the power is first turned on, or by pushing the master reset button, operation will begin in loop 1. In this loop, the decoded BCD time word will be compared with the accumulating register. If they compare, flag 1 will be presented to the buffer together with the time word. If they do not compare, flag 2 will be presented to the buffer accompanied by the time word.

In this loop the decoder will also determine if the serial decimal circuit is in synchronism with the incoming serial decimal code. If the serial decimal circuit is in synchronism with the incoming signal, the appropriate part of the incoming BCD time word is compared with the serial decimal time word. If they do not compare favorably (flag 9), the BCD circuit is automatically checked for circuit malfunction. If there is no circuit malfunction a determination is made as to whether or not the BCD circuit is in synchronism with the incoming BCD time code. If it is in synchronism a new BCD time word is set in the accumulating register and updated. If there is a BCD circuit malfunction, the BCD circuit operation is inhibited and the decoding function is shifted to loop 2. Another way to shift the decoding function to loop 2 is to have the BCD time word and the accumulating register not agree for a number of consecutive times, where the number is selective. Initially the number has been set for three times.

Operation of the decoding function in loop 2 is similar to that in loop 1 except that the serial decimal code is used in place of the binary coded decimal code. However, since the BCD loop is the more desirable

FUNCTIONAL LOGIC DIAGRAM

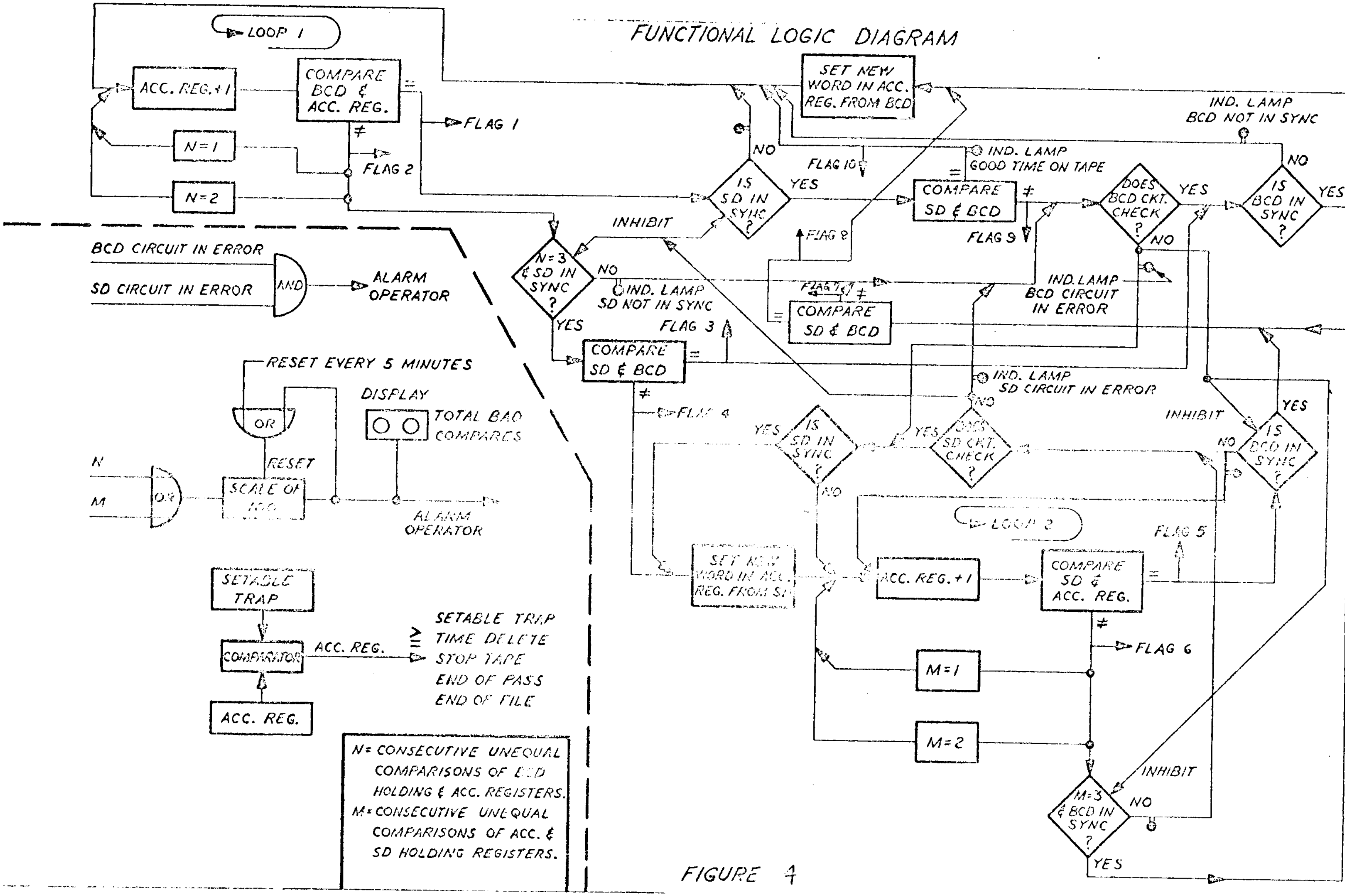


FIGURE 4

loop, because of the BCD time code characteristics described under "Time Codes", the decoder will continually determine if operation in loop 1 is possible; and if so, it will shift the decoding function back to that loop.

Conclusions

An error detection and correcting time decoder has been designed for use with satellite data reduction facilities to cope with the large number of erroneous time readings. This decoder is an improvement over the straightforward instance-by-instance time decoding (called multiple read-in) in that short-term perturbations in the time code will not produce an incorrect output from the decoder. This decoder is an improvement over a single read-in method of data-time decoding updated by a standard frequency, in that it continually correlates the time words with the data. The decoder further decodes both a serial decimal time code and a binary coded decimal time code, compares them with each other and with the accumulating register, and "flags" each time reading to indicate the amount of confidence the experimenter can place in its accuracy. It also incorporates self-checking circuits to reduce the probability that a malfunctioning decoder component will provide an incorrect time reading.